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JPRS: 26,638

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CERAMIC FLUX IN WELDING SOME ALLOYS

- USSR -

Svarka spetsial'nykh metallov i splavov
Kiev, 1963

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Price: $3.00

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CERAMIC FLUX IN WELDING SOME ALLOYS

- USSR -

Following is a translation of four articles from the Russian-language book Svarka spetsial'nykh metallov i splavov (Welding of Special Metals and Alloys), Published by the Academy of Sciences Ukrainian SSR, Institute of Electrical Welding imeni Ye. O. Paton, Kiev, 1963. Complete bibliographic information accompanies each article.

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CERAMIC FLUXES FOR AUTOMATIC WELDING OF ALLOYED STEELS

p5 D. M. Kushnerev per orig.

[Following is a translation of an article by D. M. Kushnerev in the Russian-language publication Svarka spetsial'nyyx metallov i splavov (Welding Special Metals and Alloys), edited by K. K. Khrenov, Academy of Sciences Ukrainian SSR, Institute of Electric Welding imeni Ye. O. Paton, Kiev, 1963, pp 89 -- 98.]

The quality of welding of alloyed steels in general can be estimated only as far as the propertys of a welded joint of alloyed steel correspond to properties of the basic metal. Only that technology of welding, by which the whole complex of properties possessed by the alloyed steel is obtained in the fused metal, can be considered as satisfactory.

For great reliability of welded structures, mechanical characteristics of metal of the seam and welded joint must have a certain margin, as compared to the basic metal, mainly, of plasticity and viscosity. The necessity of such a margin of durability, especially plasticity and viscosity, is caused by the possibility of formation in welded seams of various micro- and macrodefects, and by the appearance of concentrations of stresses, connected with the form of welded structures.

The quality of welded seams during welding of alloyed steels depends on the chemical composition and structure of

the fused metal. In order to obtain the required chemical composition, it is necessary to alloy a fused metal. At present the basic and most wide-spread method of alloying metal of a seam with automatic welding under flux is the use of analloyed electrode wire.

This is the most reliable, and at first glance, the simplest method of alloying. However, this method of alloying frequently is connected with significant difficulties. If one were to use an electrode wire of the same brand, as the alloyed steel being welded, then the metal of the seam, as a rule, will not have the same chemical composition as the wire. As a result of oxidation in the process of welding, the content of alloyed elements in metal of the seam will always be lower than in the electrode wire. This especially pertains to elements (aluminum, titanium, silicon and others), which possess a high chemical affinity to oxygen. Therefore, if it is necessary to obtain fused metal with the same chemical composition as the basic metal by means of alloying with an electrode wire, then one should use an electrode wire with a large content of the alloying elements.

Inasmuch as elements of the wire burn at a various degree, then the selection of the optimum composition of electrode wire frequently is quite difficult. Furthermore, frequently it is necessary in addition to alloy fused metal with elements, which are not contained in the basic metal, to change the chemical composition of the fused metal as compared to the basic metal to increase stability against the formation of cracks, which adjoin a seam of specific properties, to obtain a definite quantity of ferrite phase, etc. All this places a difficult problem on the metallurg industry, since production of various brands of alloyed wire is required. However GOST provides only a limited assortment of alloyed electrode wires, where part of them is very deficient. This means that it is necessary to use alloyed wire of by far not optimum composition to the damage of the quality of welding. During automatic welding another method of alloying may be used -- alloying with a flux. Fused fluxes, which are the widest used in industry, do not alloy. In the composition of fused fluxes only oxides of metals and certain salts can be introduced, metals or ferroalloys are not introduced in them.

In this respect ceramic non-fused fluxes possess certain advantages, with the help of which it is possible practically without limit to alloy fused metal with any element used in metallurgical production.

Ceramic fluxes constitute a mechanical mixture of thinly pulverized components, cemented by a soluble glass and prepared in the form granules, as large as necessary (fig. 1). Every grain of ceramic flux is uniform by composition and specific gravity, therefore during use of ceramic fluxes separation by separate component parts does not occur in them.

Inasmuch as in the process of the manufacture ceramic fluxes are not melted, besides slag forming mineral components, such as marble fluorspar and others, deoxidizing agents and alloying components areintroduced into their composition; ferroalloys or powders of technically pure metals.

At present there is sufficient experimental data to calculate the quantity of alloying elements, which must be introduced in the composition of a ceramic flux to obtain metal of the seam of practically any given composition. Moreover, in the majority of cases alloyed steels under a ceramic flux are welded with the use of an ordinary low-carbon electrode wire. In certain cases, when metal of the seam should be highly alloyed, it is more convenient to use a standard alloyed electrode wire and additionally to alloy metal of the seam with a ceramic flux.

The advantages of ceramic fluxes are not limited only to alloying. The quality of metal of welded seams depends not only on the chemical composition, but also on the structure of the metal. Cast metal, as known, is worse than rolled mainly due to defects of a structural character. Inasmuch as metal of the seam, as a rule, is not subjected to subsequent machining (forging), it is very important during welding to apply special measures for improving the structure of the fused(even those of the same chemical composition as the basic metal) metal. Without this mechanical properties of metal of the seam are lower than the mechanical properties of alloyed, steels, either rolled or forged.

A very effective method of improving the structure of

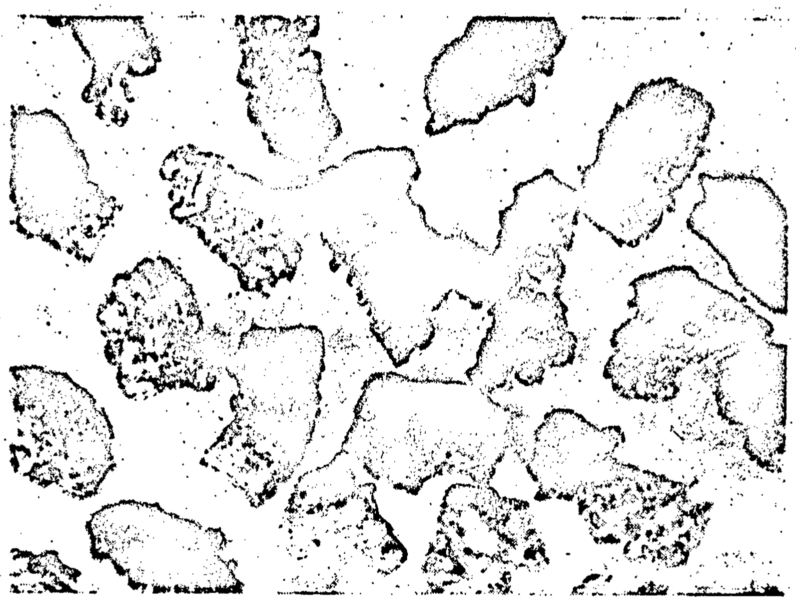

Figure 1. Granulated ceramic flux
(magnified 15 times)

metal is modification. It is widely applied in metallurgy and recently has started to be applied for welding.

The means of modification -- the introduction in metal of the seam of small additions of modifies (titanium, aluminum, calcium and others) manages strongly to crush the primary structure of fused metal and thus increase the mechanical properties of metal of the seam, but mainly -- increases stability of seams against formation of hot cracks.

Experience shows that the effectiveness of modification depends by what method modifiers are introduced in the fused metal: through a flux or through an electrode wire. At present it has been determined that with the introduction of modifiers through a wire, as a rule, crushing of the structure and increase of mechanical properties of metal of the seam is not observed. With introduction of modifiers in a composition of ceramic fluxes a crushed, equiaxial structure of metal of the seam (fig.2), very high mechanical properties and high stability of seams against formation of cracks is obtained.

Different action of modifiers during introduction of them through wire of flux can be explained by the fact that they fall in metal of the welding bath at various temperature conditions. Being in an electrode wire, modifiers are subjected to the highest heating. At the same time it is known that modifiers are deactivated as a result of overheating. In foundry production modifiers, as known, are introduced in the ladle before pouring. With introduction through a flux, modifiers are not subjected to such intense heating, a significant part of modifiers is precipitated from the smelted flux directly in the liquid metal before its crystallization.

We will note one more fundamental advantage of ceramic fluxes for welding of alloyed steels. As it is known, there always hydrogen in the gas phase of an arc. During welding under flux is dissolved in drops of the electrode metal during their transfer from the electrode to the article. Hydrogen promotes formation of hot cracks in metal of the seam and cracks in the zone near the seam during welding of hardened alloyed steels. But during welding under ceramic flux the content of hydrogen in the fused metal is significantly reduced.

This is attained by the introduction in the composition of ceramic fluxes of carbonates and the highest oxides of manganese or iron. Carbonates, for instance $CaCo_3$, introduced in a flux in the form of marble, dissociate in the process of welding, liberating in an arc interval significant quantities of carbon dioxide and oxygen. The latter in this case is not dangerous, since ceramic fluxes will deoxidize the welding bath. Gaseous products of the dissociation of carbonate from calcium sharply lower the partial pressure of hydrogen in the gas phase. Experimentally it has been determined that in metal of the seam during welding under a ceramic flux on the base of marble there is almost three times less hydrogen than in metal, fused for instance, under AN-348A flux.

High-basic ceramic fluxes on the base of marble make it possible to reduce the content of sulfur in the fused metal, increasing thereby stability of seams against formation of hot cracks. All of these peculiarities of ceramic fluxes make it possible to obtain a very high quality of welding

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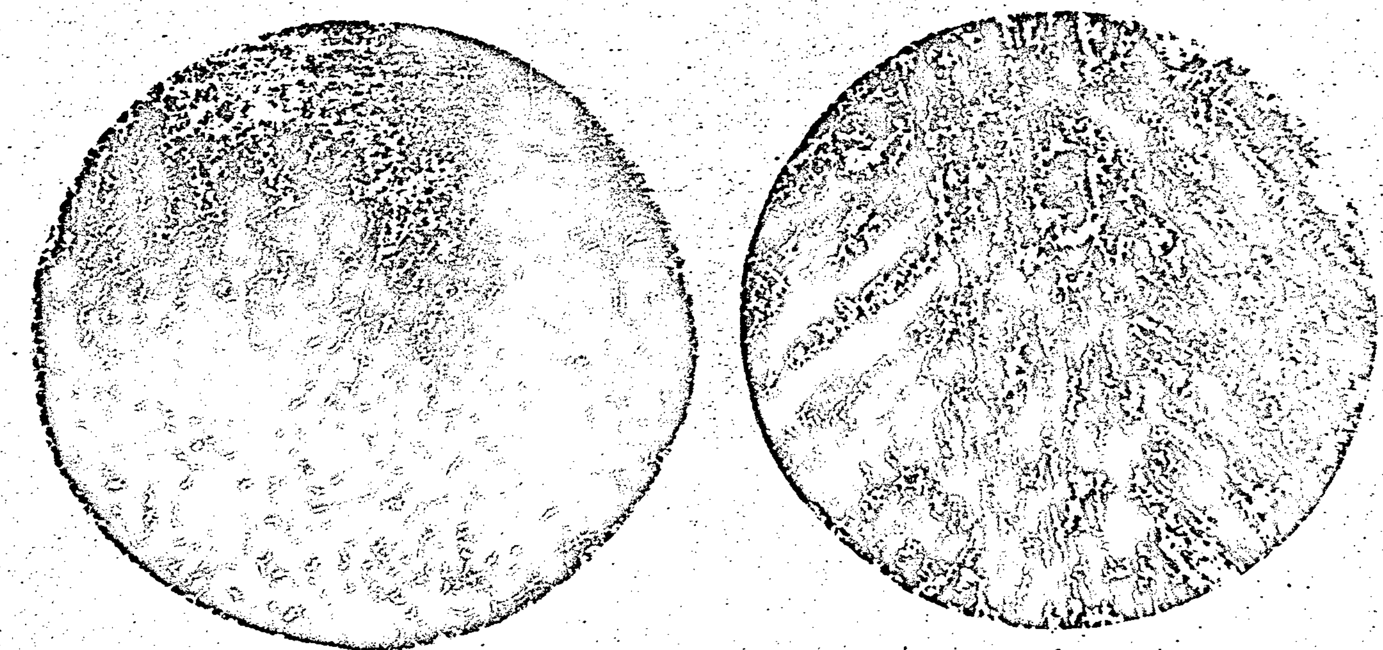

a b

Figure 2. Primary structure of metal, fused in identical conditions under ceramic and fused fluxes (magnified 45 times): a -- equiaxial primary structure of metal of the seam, KS-1 ceramic flux, b -- columnar primary structure of metal of the seam with a zone of weakening, CSTs-45 flux.

alloyed steels. As a rule, metal of the seam is obtained which is not inferior in mechanical properties to the basic metal, and sometimes exceeds it.

As example in Table 1 results of automatic welding of several brands of medium alloyed steels under ceramic fluxes, developed in the Institute of Electrical Engineering of the Academy of Sciences Ukrainian SSR are given /1/.

High mechanical properties of metal of the seam are obtained during welding under ceramic fluxes (table 1) of standard low-carbon welding wire of brand SV-08A. Ceramic fluxes during automatic welding of medium alloyed steels ensure high stability of seams against formation of cracks, possess good technological properties during welding on AC as well as on DC. With welding of medium alloyed steels under ceramic flux a sufficiently constant chemical composition of metal of the seam is obtained. The conditions met in industry of oscillation of parameters of conditions of welding do not render an essential influence on the chemical composition of welded seams or on the quality of welding.

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At present sufficient experience has been accumulated on automatic and semiautomatic welding under ceramic flux of alloyed steels of the perlitic class as well as certain brands of high-alloyed austenitic steels.

During welding of high-alloyed austenitic steels besides the usual requirements of high mechanical properties, absence of cracks, pores and others specific requirements are presented for instance, stability of seams against intercrystallite corrosion, stability against overall corrosion in different aggressive media stability against formation of cinders, and heat resistance. In order to give a seam these properties, in most cases it is necessary besides alloying by basic elements of austenitic steels -- chromium and nickel -- to add niobium, silicon, molybdenum, tungsten and other elements to obtain special physical properties of metal of the seam.

The structure of metal of the seam has a special meaning during welding of high-alloy chrome-nickel steels. For increasing stability of seams against formation of

Table 1.

(1) Марка стали	(2) Марка флюса	(3) Термическая обработка сварного соединения	(4) Предел прочности металла, $Мн/м^2$		(5) Относительное удлинение металла, %		(a) Относительное сужение металла, %		(b) Ударная вязкость металла, $кн/м$, при температуре, °K							
									293		233		213		113	
			(6) основного	(7) наплавленного	основного	наплавленного	(c) основного	(d) наплавленного	основного	наплавленного	основного	наплавленного	основного	наплавленного	основного	наплавленного
25ХГФА	КС-25ХГФА	Высокий отпуск	598	620	18,7	19,2	62,5	55,6	1030	1060	323	658	284	570	—	—
»	»	Нормализация с последующим отпуском	796	770	18,2	18,8	62,1	62,8	1118	1085	995	970	725	765	—	—
30ХГСНА	КС-30ХГСНА	Изометрическая закалка на $\sigma_в = 1560 \div 1760$ $Мн/м^2$	1660	1620	10,0	10,1	35,0	35,8	610	590	580	530	—	—	—	—
12Н3	КС-12Н3	Нормализация с последующим отпуском	490	510	28,1	29,7	61,2	59,4	1310	1180	—	—	—	—	718	738

KEY: Col 1.) Brand of steel: 25 KhGFA, 30 KhGSNA, 12N3; Col 2.) Brand of flux: KS-25KhGFA, KS-30KhGSNA, KS-12N3; Col 3.) Heat Treatment of welded joint: high temper, normalization with subsequent tempering; isometric hardening at σ_{B} = 156 ÷ 1760 Tons/m^2, normalization with subsequent tempering; 4.) Ultimate strength of metal in tons/m^2; 5.) Specific elongation of the metal in percent; 6.) Basic; 7.) Fused; a.) Specific contraction of the metal in percent; b.) Resilience of metal in Kn/m, at a temperature in degrees Kelvin; c.) Basic; d.) Fused.

crystallized cracks during welding of austenitic steels, it is desirable to have in the initial structure of metal of the seam a definite quantity of the ferrite phase. At the same time an increase of the content of the ferrite phase evokes embrittlement of metal of the seam in conditions of high-temperature exploitation. An optimum quantity of ferrite phase in the initial structure of welded seams is ensured by alloying metal of the seam with ferrite or austenite forming elements.

For additional alloying of a fused metal during welding of austenitic chrome-nickel steels, many different brands of electrode wires are necessary, frequently of a very complicate chemical composition with a content of elements within a narrow range. The usual limits of the content of individual elements in an electrode wire cannot guarantee, for instance, that in the initial structure of welded seams the ferrite phase required will be of a sufficiently narrow range. During manual welding in the composition of electrode coverings is introduced the necessary quantity of alloying elements.

During automatic welding under flux for obtaining the given chemical composition and structure of metal of the seam ceramic fluxes are applied, with the help of which fused metal can be alloyed within wide limits and with sufficient accuracy.

In principle ceramic fluxes make it possible to obtain

high-alloyed austenitic fused metal during use of low-carbon welding wire of brand Sv08. However, such fluxes are not technologically effective, they contain a large quantity of alloying components, which for obtaining stable chemical composition of metal of the seam it is necessary to observe exactly the given conditions of welding.

It is more expedient during welding of austenitic steels to use ceramic fluxes only for additional alloying and modification of fused metal, basic alloying of metal of the seam (chromium and nickel) is done by wire. With this it is possible to manage with a limited number of the simplest by composition standard austenitic wires.

Table 2.

(a) Объект анализа	(b) Содержание элементов, %										
	C	Mn	Si	S	P	Cr	Ni	Ti	O_2	N_2	H_2
Металл шва (c)	0,08	1,2	0,7	0,012	0,039	18,7	9,6	0,30	0,004	0,014	0,00048
Проволока СвХ18Н9Т (d)	0,07	1,28	0,25	0,009	0,037	18,46	8,48	0,5	—	—	—
Основной металл (e)	0,09	1,39	0,49	0,014	0,026	18,86	9,98	0,62	—	—	—

Chemical composition of fused metal during welding of 1Kh 18 N9T steel under K-8 ceramic flux.

KEY: a) Object of analysis; b) Content of elements in percent; c) Metal of the seam; d) Sv1Kh18 N9T wire; e) Basic metal.

Table 2 gives certain results of the application of K-8 brand ceramic developed in the Institute of Electrical Engineering of the Academy of Sciences of Ukrainian SSR for automatic and semiautomatic welding of the most wide-spread in industry austenitic chromonickel 1Kh18N9T steels [2].

K-8 ceramic flux is applied in combination with

SvlKhl8N9T brand standard welding wire. Flux K-8 is composed on the basis of a slag system CaO -- MgO -- TiO_2 -- AL_2O_3 -- CaF_2 with a significant predominance of basic oxides. The flux during welding both on AC and DC ensures good forming of seams and easy separation of slag crust, high durability of seams against formation of pores and cracks. During welding of 1Khl8N9T steel under ceramic flux does not produce intensive oxidation of chromium and titanium. Metal of the seam is distinguished by a very low content of oxygen and hydrogen. For durability and plasticity seams during welding under ceramic flux do not exceed the basic metal. Average indices of mechanical properties of metal of the seam and a welded joint during welding of 1Khl8N9T steel under K-8 flux are:

(a) Марка флюса	(b) Сварочная проволока	(c) Предел прочности, $Мн/м^2$	(d) Относительное удлинение, %	Относительное сужение, %	(e) Ударная вязкость, $\frac{кн}{м}$	(f) Угол загиба, рад
К-8	Св1Х18Н9Т	570	56,0	65,0	1570	3,14

KEY: a) Brand of flux; b) Welding wire; c) Ultimate strength in tons/m^2; d) Specific elongation in percent; e) Specific antraction in percent; f) Resilience in Kn/m; g) Angle of bend in radians.

Soaking at a temperature of 1023 degrees K during 1,000 hours does not lead to a significant lowering of resilience of a welded joint, carried out under flux, as shown below.

During welding under K-8 flux metal of the seam has a two-phase austenitic-ferrite structure with a content of ferrite near 5 percent. Seams welded under K-8 flux are stable against intercrystallite corrosion both after welding as well as after two-hour tempering at 923 degrees K. A welded joint of 1Khl8N9T steel also showed high stability during a test for overall corrosion.

(a) Марка флюса	(b) Сварочная проволока	(c) Ударная вязкость, кн/м, после выдержки при 1023°К, ч				
		0	2,5	250	500	1000
К-8	Св1Х18Н9Т	$\frac{1450 \div 1500}{1476}$	$\frac{1420 \div 1470}{1450}$	$\frac{1400 \div 1450}{1430}$	$\frac{1340 \div 1478}{1400}$	$\frac{980 \div 1270}{1138}$

KEY: a) Brand of flux; b) Welding wire; c) Resilience, in Kn/m, after soaking at 1023 degrees K. for hours indicated.

Ceramic K-8 flux during the recent years has been used at a number of plants for automatic and semiautomatic welding of 1Kh18N9T steel with a thickness of from 5 to 30mm. Welding under this flux, for instance, in the "Krasnyy Oktyabr" Plant (in the city of Fastov of Kiev Oblast) has been conducted only on alternating current. Possibility of automatic welding of austenitic steels under ceramic flux on alternating current is a valuable advantage of the given technology.

Besides usual ceramic fluxes, for automatic welding by closed arc lately a special form of these fluxes has found use -- so-called magnetic ceramic fluxes by which an individual article is given into a receptacle.

Ceramic fluxes at present are manufactured at those plants at which they are used. The technology of their production is similar to the process of manufacturing electrode coverings. Therefore organization of production of ceramic fluxes in small volume in efficient electrode shops is not connected with considerable expenditures and easily can be carried out on the base of a variety of equipment of electrode production.

In the nearest time centralized industrial production of ceramic fluxes in Dnepropetrovskaya and Kuybyshevskaya Sovnarkhozes in a volume of 10,000 tons of flux per year will be organized.

Bibliography

1. K. K. Khrenov, D. M. Kushnerev, Keramicheskiye flyusy dlya avtomaticheskoy svarki i naplavki (Ceramic Fluxes for Automatic Welding and Seam Welding), Gostekhizdat Ukrainian SSR, 1961.

2. D. M. Kushnerov, M. P. Grebel'nik, "Keramicheskiy dlya avtomaticheskoy svarki nerzhaveyushchey stali marki 1Kh18N9T" (Ceramic Flux for Automatic Welding of Stainless Steel Brand 1Kh18N9T), Svarochnoye proizvodstvo (Welding Production), No 5, 1960.

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INVESTIGATION OF AUTOMATIC WELDING OF NICKEL HEAT-RESISTING ALLOYS UNDER CERAMIC FLUX

p15

[Following is a translation of an article by D. M. Kushnerev and I. V. Lyakhovaya in the Russian-language publication Svarka spetsial'nyyx metallov i splavov (Welding Special Metals and Alloys), edited by K. K. Khrenov, Academy of Sciences Ukerainian SSR, Institute of Electric Welding imeni Ye. O. Paton, Kiev, 1963, pp 111 -- 120]

The basic difficulties of welding high-alloyed heat-resisting alloys on a nickel base are: a) high inclination of welded seams to form hot cracks; b) necessity of obtaining fused metal, not yielding by heat resistance to the basic metal. Therefore selection of technology of automatic welding of such articles presents a complicated problem which has not been solved satisfactorily up to now in spite of efforts of collectives of a number of scientific-research organizations and plants.

Approaching fulfillment of present work on automatic welding of heat-resisting alloys, we were oriented on the application of ceramic fluxes.

The peculiarities of ceramic fluxes, their ability to alloy within wide limits and to modify fused metal opens the possibility to increase stability of seams against formation of hot cracks and simulataneously to obtain the necessary heat resistance.

Method of Investigation

During welding of heat-resisting alloys besides the usual requirement of high mechanical properties and the lack of defects in welded seams, to the fused metal is presented the basic requirement -- heat resistance, which is ensured by the use of alloys on the basis of nickel, alloyed by chromium, tungsten, molybdenum, titanium, aluminum, boron and other elements. Such alloys, as is known, are very inclined to the formation of hot cracks in the welded seams. The basic problem of investigation was to determine optimum alloying of fused metal, giving sufficient stability of seams against the formation of hot cracks and necessary heat resistance. The problem of investigation consisted of selection of additional alloying of metal of the seam through a ceramic flux, which makes it possible to increase stability of seams against formation of hot cracks. Let us give certain data [1, 2] about the influence of allouing elements on the inclination of seams to form hot cracks during welding of heat-resisting alloys on a nickel base. P20

Chromium in such alloys gives a solid solution with a narrow interval of crystallization and therefore in pure chrome-neckel alloys does not increase the inclination to form hot cracks. However, in the presence of other elements, especially silicon, the inclination of chrome-neckel alloys to formation of hot cracks is sharply increased. Thus, for pure nickel the introduction of more than 1% silicon is relatively harmless; with a content of 15 % chromium the addition of several tenths and up to 1% silicon sharply increases the inclination to form hot cracks.

Chrome-nickel alloys usually contain up to 0.20% carbon its quantity is limited by the requirement of corrosional stability of heat-resisting alloys. An increase of the content of carbon is usually compensated by the introduction of stabilizing elements, for instance, titanium, niobium. The influence of carbon on the inclination to form hot cracks to a significant degree depends on the presence of other alloying elements, especially silicon. According to [2], carbon in chrome-nickel alloys (with a content of about 33% nickel) compensates for the harmful influence of silicon on forming

hot cracks (Fig. 1). For instance, the introduction of 0.4 -- 0.5% carbon with 1% silicon makes it possible to obtain high stability of chrome-nickel seams against formation of hot cracks.

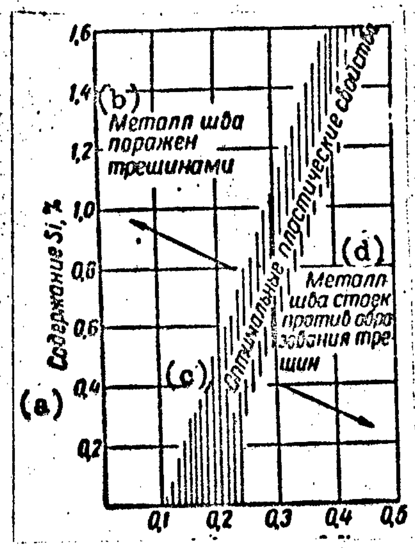

Figure 1. The influence of carbon and silicon on the stability of seams against formation of hot cracks during welding of a heat-resisting alloy containing 35% nickel /2/.

KEY: a) Content of Si, in percent; b) Metal of the seam cracks; c) Optimum plastic properties; (d) Metal of the seam stands against formation of cracks.

Up to 4% manganese in heat-resisting alloys on a nickel base, according to /1/, has comparatively little effect on the inclination to form hot cracks. At the same time the favorable influence of manganese in chrome-nickel alloys is known.

Silicon, according to the works /1 and others/, sharply increases the inclination of seams to form cracks. In chrome-nickel alloys, chromium, lowering the solubility of

silicon, promotes the formation of siliceous fusible eutectics. Silicon sharply increases liquation of other elements in chrome-nickel alloys.

Molybdenum and tungsten do not render a definite influence on crack formation of single-phase chrome-nickel alloys.

Niobium, according to certain researchers, increases the stability of heat-resisting alloys on nickel basis against formation education of hot cracks, neutralizing the harmful influence of silicon. The optimum proportion of niobium and silicon are in alloys of the composition: 75% Ni, 15% Cr, 7% Fe is count considered 4.5, and in an alloy with a composition of 35% Ni, 15% Cr, 50% Fe -- 8 to 9% [1].

Magnesium and other elements connecting sulfur suppress the reaction of formation of fusible sulfurous eutectics, increasing with this the stability of alloys against formation of hot cracks.

Aluminum is a useful addition to high-nickel alloys both as a deoxidizing agent and as a substantiating element. However, with an increase of the content of aluminum the inclination to formation of hot cracks increases, where the action of aluminum, as silicon, depends on the presence of other alloying elements.

Boron is a very useful addition in chrome-nickel alloys, it increases heat resistance, but sharply worsens the stability of seams and zones near the seam against formation of cracks with a content of more than 0.03% of it. Boron promotes formation of fusible eutectics with nickel on the boundaries of grains.

Sulfur, phosphorus, zircon and lead, as boron, form fusible eutectics on boundaries of grains and are very harmful from the point of view crack formation.

Thus, alloying elements according to the character of their influence on crack formation during welding of heat-resisting alloys on a nickel base can be divided into the

following four groups [1]: 1) favorable influence: niobium and magnesium; 2) no influence: manganese, copper, chromium, iron, cobalt; 3) renders a variable influence: aluminum, titanium, carbon, silicon, molybdenum (in single-phase region with a content of up to 10% increases stability against formation of cracks); 4) renders a harmful influence: sulfur, phosphorus, boron, zirconium, lead.

Besides alloying, one of the possible ways of increasing stability of seams against formation of hot cracks is crushing the structure of metal of the seam -- modification -- the introduction in the fused metal of small additions of elements modifiers. In this respect ceramic fluxes, as known, open wide possibilities. However, experience of modification by ceramic fluxes up to now has been limited to crushing of the primary structure during welding of carbonic, medium-alloyed and certain brands of austenitic chromo-nickel steels. In the latter case the favorable influence of small additions of titanium and aluminum on stability of seams against formation of hot cracks (metal of the seam of type Kh20N10G6) is known. On modification of metal of the seam during welding under ceramic flux of heat-resisting alloys on a nickel base of there is not any information.

According to data of certain researchers [3 -- 5] the modifying action of 0.3% magnesium, appearing in the form of a nickel-magnesium alloy in a fused metal has been determined. Also the modifying action of cerium together with calcium, favorably affecting the distribution of sulfur in poured austenitic steels has been noted.

Based on the above mentioned data about the influence ofalloying and modifying elements on the inclination of seams to form hot cracks the following method of research was selected.

The optimum compositions of the chemical composition of the fused metal were noted, which then were reproduced by means of corresponding selection of electrode wires and alloying ceramic fluxes considering the conversion factors of alloying elements from high-basic ceramic fluxes. The selected variants were tested by means of hard-facing and welding of heat-resisting alloys.

Six-layer hard-facings on plates from a heat-resisting alloy with subsequent preparation of a large section from a multilayer hard-facing served as the first appraisal of the stability of the selected composition against formation of hot cracks. Each subsequent layer was fused after complete cooling of the preceding. In the process of the experiments a slag-forming base of a ceramic flux was also worked out.

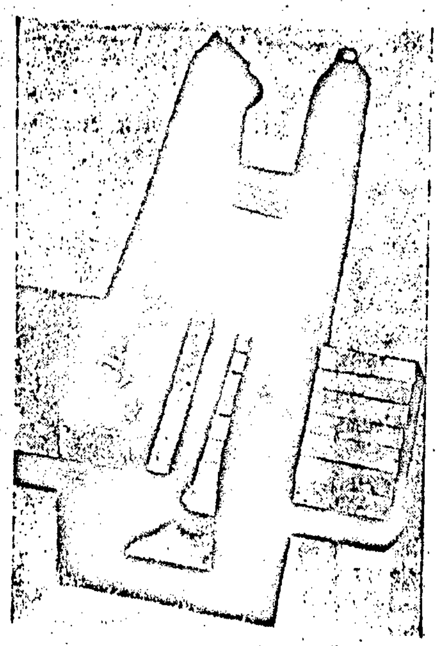

Figure 2. Device for Welding End to End Samples of Heat-Resisting Alloys.

Further selected variants were tested by means of hard-facing a shaft on compound samples of heat-resisting alloy of brand LV7-45U and also welding end to end a set of samples of this alloy (crusts) to plates of alloy of brand EI-437-B.

Hard-facing of shafts on a set of compound, as known, is a sufficiently rigid test characterizing the stability of fused metal to form hot cracks [7]. For execution of tests

by this method a special device was prepared (Figure 2), which makes it possible to secure rigidly a set of samples with a determined force controlled by a dynamometric key.

After welding, the compound samples were broken. The approximate measure of the inclination of the fused metal to form cracks was the proportion of the area occupied by a hot crack in the break to the entire area of the break.

The third form of tests, the closest to conditions of welding articles was the two-way welding of "crusts" to plates. Preparation of edges was the same as in articles under welding. This form of tests makes it possible to estimate the stability against formation of cracks of real seams corresponding to seams on articles. Welding of joint seams was conducted on selected and rigidly secured samples in the device (Figure 2). Seams were estimated by the form and length of cracks leading to the surface.

During the investigations VL7-45U, EI-437B metal alloys, brands EI-868, EI-395, SvKh20N10G6 welding wires, and alloying components of ceramic fluxes: ferrotitanium, ferroaluminum, ferroniobium, ferrocerium, alloys of aluminum-niobium, nickelmagnesium, chromoniobic, were used. P25

The chemical composition of welding materials is given in Table 1 and 2.

Description of Experiments

First preliminary experiments had as a purpose the selection of a slag forming basis of a ceramic flux, useful for welding heat-resisting alloys by thin wire with a diameter up to 1.6 mm. Use of thin wire in this case is connected with the heat-physical properties of heat-resisting alloys, the welding of which, as known, is conducted with small linear energy. As slag forming components were selected those containing mainly oxides of a basic character and possessing minimum oxidizing properties. The use of marble in this case we considered permissible by the considerations presented in detail in the work [7]. Besides marble, in the composition of experimental fluxes were introduced fluorspar, titaniu, dioxide, magnesium oxide, aluminum oxide. The proportion of slag forming components in the first experimental

Table 1.

Chemical Composition of Basic Metal and Welding Wire

(a) Материал	(b) Марка сплава	(c) Содержание элементов, % C	Mn	Si	Cr	Ni	Ti	Mo	Fe	W
(d) Основной металл	ВЛ7-45У	0,20—0,22	0,36—0,41	0,19—0,39	18,4—19,1	41,2—41,5	0,02—0,03	—	27,9—23,7	7,82—8,23
	ЭИ-437Б	0,08	—	0,42	20,42	76,6	2,3	—	—	—
(e) Сварочная проволока	ЭИ-868	0,06	0,21	0,34	23,55	57,3	0,45	—	2,8	13,0
	ЭИ-395	0,07	1,47	1,11	15,5	24,0	0,05	5,1	—	—

KEY: a) Material; b) Brand of alloy; c) Content of elements, in percent; d) Basic metal; e) Welding wire; f) VL7-45U; g) EI-437B.

Table 2.

Chemical Composition of Alloying Components of Ceramic Fluxes

(a) Наименование	(b) Содержание элементов, % Ti	Al	Nb	Mg	Ni	Cr	Si	Fe	Cu	C	S	P
(c) Ферротитан (Тн-0)	27,9	6,7	—	—	—	—	5,1	—	2,2	0,1	0,03	0,021
(d) Ферроалюминий	—	48,3	—	—	—	—	—	51,0	—	—	0,003	0,010
(e) Алюминийниобиевая лигатура	—	11,0	86,0	—	—	—	—	—	—	—	—	—
(f) Никелемагниевая лигатура	—	—	—	20,0	79,0	—	—	—	—	0,03	—	—
(g) Хромониобиевая лигатура	—		71		—	27,0	—	—	—	—	—	—

KEY: a) Type designation; b) Content of elements, in percent; c) Ferrotitanium (Tn-0); d) Ferroaluminum; e) Aluminum-niobium alloy; f) Nickel-magnesium alloy; g) Chromoniobic alloy.

fluxes were selected according to the type of ceramix flux of the K-8 brand, intended for welding austenitic chrome-nickel steels of type 18-8 and namely: 60% $CaCO_3$; 6% CaF_2; 15% TiO_2; 10% MgO; 5% Al_2O_3. As deoxidizing agents in these fluxes ferrotitanium and ferroaluminum were introduced. Fluxes of this type were tested by means of a six-layer hard-facing by SvKh20N10G6 wire with a diameter of 1.2--1.6 mm and technological properties showed fully satisfactory results. However during transition to a multilayer hard-facing of thin wire of brands EI-395 and EI-868, the selected slag forming basis did not ensure normal forming of fused metal, on the surface of seams hollows and characteristic cracks were observed.

Variation of the content of each of the components of the selected basis of experimental fluxes showed that forming of fused metal during welding by a thin wire is improved with lowering the content of Al_2O_3. Excluding alumina from the composition of the ceramic flux made it possible to obtain sufficiently high technological properties of fluxes with a different content in them of the alloying components.

Further experiments were conducted with six-layer hard-facings on plates with a thickness of 30 mm of 1Kh18N9T austenitic steels with wire of brands EI-395 and EI-868 under ceramic fluxes, in the composition of which besides slag forming components 6% ferrotitanium and ferroaluminum were introduced. Hard-facing was conducted on dc of reverse polarity with a current intensity of 220--300 amps, an arc voltage of 25--27 volts, a welding speed of 7 mm/sec, by a wire with a diameter of 1.6 mm. During external inspection of hard-facings and consideration of microsections cut from the metal, cracks were not revealed. These experiments, however, could not serve as a base for positive appraisal of the stability of fused metal of the obtained composition against formation of cracks, since a pure metal was subjected to the test (without participation of a basic metal containing such elements as boron and others). Furthermore, the condition of crystallization of welding baths are far from real conditions of hardening metal of the seam on articles. Confirmation of this are the first hard-facings by EI-395 and EI-868 wires on compound samples of the VL7-45U alloy. During welding of samples, it turned out that in the case of hard-facing under ceramic fluxes, indicated above, by EI-395 wire hot cracks occupied the entire area of the crack. During hard-facing by EI-868 wire the area occupied by the crack decreased.

A possible cause of the decrease of the inclination of fused metal to form hot cracks during welding by EI-868 wire is the lower content in it of silicon (0.34% Si) as compared to EI-395 wire (1.11% Si). This assumption is confirmed by complete destruction of compound samples (a crack occupies the entire area of the break) during welding by EI-868 wire under fluxes containing more than 0.5% ferrosilicon.

Ceramic fluxes, in which as a compound component soluble glass is used (water solution of sodium silicate), introduce a certain quantity of silicon in the fused metal. Therefore it was necessary to replace the soluble glass with other compound agents.

As a substance, close by chemical and physical properties to sodium silicate sodium aluminate was selected, a water solution of which, as experiments showed has the necessary adhesive properties. A water solution of sodium aluminate was relatively easily obtained by us in the laboratory by means of dissolving waste aluminum (preliminarily defatted) in boiling technically pure caustic soda. Boiling of the solution is continued up to obtaining of the necessary density of 1.5 -- 1.6.

As further experiments showed replacement of soluble glass by sodium aluminate did not reflect on the technological properties of the ceramic flux and did not introduce any changes in the manufacturing of the flux.

For determination of the influence of a change of adhesive agent on the content of silicon in a fused metal four-layer hard-facings were carried out by SvKh2010G6 wire uner V-3 and V-3a fluxes (Table 3), differing only by the adhesive component. V-3 flux was mixed in soluble glass, and V-3a flux -- in sodium aluminate. Their compositions are given in Table 4.

In the V-3 flux In-3 there is 17% of the total weight of the charge soluble glass with a density of 1.35, and in V-3a flux 22% of the total weight of the charge sodium aluminate with a density of 1.5.

Table 3 gives the chemical composition of a metal,

Table 3.

Chemical composition of fused metal, in percent

Марка флюса (a)	C	Mn	Si	Cr	Ni	Ti
B-3	0,10	5,07	0,33	16,47	10,02	0,1
B-3a	0,10	4,37	0,14	16,93	10,3	0,05

KEY: a) Brand of flux

Table 4.

Composition of charge of experimental fluxes, in percent

(a) Марка флюса	(b) Мрамор	(c) Плавиковый шпат	(d) Двуокись титана	(e) Магнезитовый кирпич	(f) Ферротитан	(g) Ферроалюминий
B-3	61	6	14	9	5	5
B-3a	61	6	14	9	5	5

KEY: a) Brand of flux; b) Marble; c) Fluorspar;
d) Titanium dioxide; e) Magnesia brick;
f) Ferrotitanium; g) Ferroaluminum.

fused by SvKh20N10G6 wire with a diameter of 1.6 under v-3 and V-3a flux. Hard-facing was conducted on DC of reverse polarity with a current intensity of 300 amps, arc voltage of 30 volts, speed of welding of 7 mm sec.

As seen, replacement of soluble glass by sodium

aluminate made it possible to lower the content of silicon in the fused metal by almost three times.

Based on experiments conducted subsequently experimental ceramic fluxes were prepared with the use of sodium aluminate.

For study of the inclination of fused metal to form cracks under conditions, close to real, we welded end to end crusts from VL7-45U alloy to plates EI-437B by EI-868 and EI-395 wires; this modified additional alloying by the following form.

1. Additional alloying of metal of the seam through a ceramic flux by niobium in a quantity exceeding approximately five times the content of silicon.

2. Introduction of niobium in a quantity eight-nine times exceeding the content of silicon.

3. Introduction in the composition of the flux of graphite for the purpose of obtaining optimum relationship of carbon to silicon in accordance with the data shown in Figure 1.

4. Introduction in the composition of the ceramic flux of different quantities of nickel-magnesium alloy.

5. Introduction in the composition of the ceramic flux of different quantities of ferrocerium.

6. Complex alloying of the fused metal by niobium, magnesium and cerium.

Numerous experimental fluxes of different composition were prepared. Welding of joint seams under experimental fluxes was done with wires with a diameter of 1.6 mm on DC of reverse polarity with a current intensity of 280 -- 300 amps, arc voltage of 28 -- 30 volts, speed of welding 7m/sec. Joints were welded with straight seams on each side. The second side of joint was welded after full cooling of the first seam. Shavings for chemical analysis were collected from metal of the seam of the first passage.

As a result of the experiments conducted it was determined that during welding of end to end samples of heat-

resisting alloys by the above described method seams without cracks were not obtained. In all seams transverse cracks were observed which are a continuation of the gap between crusts. However, the length of cracks with various variants alloying was different.

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Thorough consideration of samples made it possible to determine that the smaller length of transverse cracks have seams, welded by EI-395 wire under ceramic fluxes, containing a sufficiently large quantity aluminum-niobium alloy. The best results on stability against formation of cracks were given by 1-V6 flux (Table 4) in combination with EI-395 wire. Metal of the seam in this case contains more than 2.5% niobium. The composition of the charge of the experimental 1-V6 ceramic flux is: 41% marble, 6% fluorspar, 14% titanium dioxide, 9% magnesia brick, 5% ferrotitanium and 25% aluminum-niobium alloy.

As a result of the investigations conducted bearing an exploratory and preliminary character, nevertheless it was determined that and preliminary character, nevertheless it was determined that the change chemical composition and structure of metal of the seam by alloying and modification of fused metal by ceramic flux, can to a significant degree affect the stability of the seam against formation of hot cracks during welding of heat-resisting alloys under conditions very close to welding of real articles. Alloying of metal of the seam by niobium, introduced in the fused metal through ceramic flux, makes it possible to increase stability of seams against formation of hot cracks.

Further development of this work could be a detailed study of the influence of alloying elements on the structure of metal of the seam, and also improvement of the method experiments, which would allow more exactly to estimate the relative influence of alloying elements on the stability of seams against formation of hot cracks.

Bibliography

1. E. R. Pease, "The Practical Welding Metallurgy of Nickel and High-nickel Alloys", The Welding Journal, V. 36, No 7, 1957.

2. E. M. Anger, W. E. Dundon, G. Thompson, "How to Weld the Heat Resistant Alloys", Welding Engineer V. 38, 1938.

3. C.A. Iodkowskiy, Problemy vyroby velkych tuarovych odlitku z austeniticke zaropevne oceli, Hafn. akutal, 1958, 16.

4. N. S. Kreshchanovskiy, R. N. Zaletaeva, (Influence of Magnesium on the Surface of Tension, Supercooling and Crystallization of Austenitic Steels), "Vliyaniye magniya na poverkhnosti natyazheniya, pereokhlazhdeniya i kristallizatsiyu austenitnoy stali", Liteynoye proizuodstvo (Foundry Production) 1953, III, No3.

5. N. S. Kreshchanovskiy, I. K. Zabludovskiy, (The Influence of Modifiers on Crystallization and Distribution of Sulfur in Cast Austenitic Steels), "Vliyaniye modifikatorov na kristallizatsiyu i raspredeleniye sery i litoy austenitnoy stali", Metaliovedeniye i termoobrabotka (Metal Working and Heat Treatement), 1959, No 3.

6. W. R. Apblett, W. S. Pellini, "Factors Which Influence Weld Hot cracking," The Welding Journal, No 2, 1954.

7. D. M. Kushnerev, M. P. Grebel'nik, Ceramic flux for automatic welding of stainless steel of brand 1Khl8N9T, "Welding production", 1960, No 5.. "Keramicheskiy flyus dlya avtomaticheskoy svarki nerzhaveyushchey stali marki 1Khl8N9T," Svarochnoye proisvodstvo (Welding Production), 1960, No 5.

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WELDING WITH THE USE OF MAGNETIC CERAMIC FLUXES

) p 33 →

[Following is a translation of an article by D. M. Kushnerev and V. G. Svetsinskiy, in the Russian-language publication Svarka spetsial'nyyx metallov i splavov (Welding Special Metals and Alloys), edited by K. K. Khrenov, Academy of Sciences Ukrainian SSR, Institute of Electric Welding imeni Ye. O. Paton Kiev, 1963, pp 121 -- 128.]

Recently in our country and abroad a new method of semiautomatic electric arc welding with the use of magnetic ceramic flux is being used. In the USSR this method was suggested for the first time in 1950 by A. I. Xodzhayev.

A distinctive peculiarity of magnetic flux is its ability to be attracted to a bare welding wire during passage on it of a welding current due ferromagnetic substances in its composition. Around the wire at the range of departure a covering from ceramic flux of small granulation is formed. The wire together with the flux passes through a nozzle with a calibrated hole into the zone of burning of the arc (Fig. 1). The dimension of the hole of the nozzle ensures the necessary proportion between quantities of the melted flux and wire. Spontaneous breaking-out of the flux through the hole of the nozzle during breaks in welding is prevented by a circular permanent magnet installed in the nozzle. The magnet does not prevent passage of the flux through the nozzle during welding, since the magnetic field, created by the welding

current, is more intense than the magnetic field of the permanent magnet. An electrode wire moves in the zone of the arc by the feeding mechanism of the semiautomatic machine. The arc burns in an atmosphere of air or in a medium of protective gas.

For attaching magnetic properties to the flux iron powder is usually introduced into its composition. Ferroalloys introduced into the composition of ceramic fluxes also possess certain magnetic properties, however, as experience shows, even their very high content in a flux does not ensure a reliable supply of flux together with the electrode wire. Therefore for attaching the necessary magnetic properties to a ceramic flux in its composition it is always necessary to introduce a certain quantity of iron powder.

A study of the process of welding with magnetic fluxes, conducted with the help of high-speed film (2000 frames per second)*made it possible to establish certain peculiarities of the process of fusing and transfer of the electrode metal and flux as compared to manual arc welding by qualitative electrodes.

For welding with a magnetic flux with usual densities of current (50 --100) microampere/m^2 a large-drop transfer of metal is observed. Examination of films, taken during a test of fluxes of different chemical composition, made it possible to determine that part of the grains of the flux, not passing through the arc interval, proceed directly to the welding bath in unmelted state. This opens wide possibilities for the modification of fused metal.

The method of semiautomatic welding with magnetic fluxes has a number of advantages in comparison with hand arc welding by qualitative electrodes as well as with welding under flux.

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* High-speed photography was conducted in the laboratory of the chair of welding production of the Kiev Polytechnical Institute.

The main advantage of this method as compared to hand arc welding (and in certain cases as compared to welding under flux) is the increase of productivity of the process at the expense of the increase of coefficients of hard-facing (Table 1).

The increase of coefficient of hard-facing with this method apparently, can be explained by the presence of iron powder in the flux, the use of large densities of current (as compared to hand arc welding), and also the smaller quantity of heat expended on melting the flux as compared to welding by closed arc.

Welding with magnetic flux has an essential advantage over welding by closed arc: during preservation of automatic feeding of the electrode wire the zone of welding is visible, and this allows welding of seams of complicated monfiguration, short seams and articles, where retention of the flux is hampered.

Retention of the flux by the magnetic field on the electrode wire makes it possible to execute by this method welding of slanted and vertical seams without use of special flux-holding and forming devices.

Table 1.

Productivity of Different Welding Processes

Col. (1) Сварка	(2) Диаметр электрода, мм	(3) Скорость подачи проволоки, м/сек	(4) Сварочный ток $I_{св}$, а	(5) Напряжение дуги $U_д$, в	(6) Коэффициент наплавки, мг/а·сек	(7) Время наплавки 1 кг металла, мк/сек	(8) Производительность, г/сек
Автоматическая под слоем флюса	3	0,03	300—320	28—30	4,32	68,6	1,12
Ручная электродуговая, электродами УОНИИ-13/45	5	—	220—240	25—27	2,62	213	0,360
Полуавтоматическая в среде углекислого газа	2	0,06	280—200	27—28	3,77	124	0,62
Полуавтоматическая с магнитным флюсом	2	0,071	300—330	32—34	5,71	54,8	1,40
М-10	1,6	0,071	220—240	30—32	5,33	64	1,00

KEY: Col 1) Welding; automatic under a layer of flux; Manual electro-arc with UONII-13/45 electrode; Semi-automatic in a medium of carbon dioxide; Semi-automatic with magnetic flux; M-10; Col 2) Diameter of electrode in mm; Col 3) Speed of wire feed in m/sec; Col 4) Welding current I_W in amps; Col 5) Arc voltage U_a in volts; Col 6) Coefficient of hard-facing in mg/a sec; Col 7) Time of hard-facing one kg of metal in mk/sec; Col 8) Productivity in g/sec.

The deficiencies of the method of welding with the use of magnetic fluxes be related to the necessity of exact dosage of the flux during welding for providing constancy of the chemical composition of metal of the seam.

For welding low-carbon steels by Sv-08 welding wire we developed M-10 magnetic flux. This flux is composed on the basis of the slag system CaO--MgO--SiO_2--CaF_2--TiO_2. The chemical composition of M-10 flux is: 10.5--11.0% $CaCO_3$; 6.3--7.0% MgO; 15.0--17.0% CAF_2 [sic]; 7.7--9.0% TiO_2; 12.0--15.0% SiO_2; 22.0--24.0% Fe; 3.0--3.5% Mn; 1.2--1.4% Ti; not more than 0.05% S; not more than 0.05% P; others -- up to 3.0%.

For the composition of a charge of M-10 flux components in the following weight proportions can be used:

Component	Percent
Marble (GOST 4416-48)	22
Fluorspar (GOST 4421-48)	17
Magnesia brick (GOST 4689-49)	7
Mercury concentrate (vr. TU)	9
Sand quartz (GOST 4417-48)	11
Ferromanganese (GOST 4755-49, Mn-0 or Mn-1)	4
Ferrosilicon (GOST 1415-49, Ci-75)	4
Ferrotitanium (GOST 4761-54, Ti-0)	6
Iron Powder (ChMTU 3648-58, A)	20
Sodium silicate electrode (GOST 4419-48, Class A, solution with a density of 1-30-1,32, relative total weight of dry mixture	15

The chemical composition of the fused metal on St. 3 steel carried out by semiautomatic welding with the use of M-10 magnetic flux is given in Table 2. Welding was done in the lower position by wire with a diameter of 2 mm, on DC of reverse polarity with I_w = 300--330 amps, U_a = 32--34 volts.

Table 2.

Chemical Composition of Metal in Percent

(a) Материал	C	Mn	Si	S	P
(b) Наплавленный металл	0,11	0,59	0,15	0,024	0,031
(c) Сварочная проволока	0,07	0,57	0,06	0,025	0,020
(d) Основной металл	0,15	0,49	0,10	0,029	0,033

KEY: a) Material; b) Fused metal; c) Welding wire; d) Basic metal.

Semiautomatic welding with M-10 magnetic flux ensures mechanical properties of the fused metal and welded joints near those obtained during welding by electrodes of type E-42A and E-50A (GOST 2523-51), and namely: for fused metal σ_v = 500 Tn/m²; δ_5 = 31.2%; ψ = 72.8%; a_k = 1,760 km/m; for a welded joint σ_v = 450 Tn/m2; angle of bend is 3.14 rad.

M-10 flux ensures good forming of seams, easy separation of the slag crust, lack of pores, cracks and other defects in the welded seams.

The recommended conditions of welding with the use of M-10 flux are given in Table 3.

Table 3.

Conditions of Welding

(a) Диаметр сварочной проволоки	$I_{св}$, а	$U_д$, в	$V_{под.}$, м/сек	(b) Пространственное положение
2	300—330	32—34	0,071	(c) Нижнее
2	290—310	32—34	0,061	»
2	280—300	30—32	0,053	»
1,6	220—240	26—28	0,071	(d) Наклонная плоскость
1,6	180—200	25—27	0,053	(e) Вертикальное

KEY: a) Diameter of welding wire; b) Space position; c) Lower; d) Slanted plane; e) Vertical.

The application of semiautomatic welding by austenitic wire with a magnetic ceramic flux gives a significant increase of productivity as compared to hand arc welding. For instance during welding with magnetic flux by a SvKh20N10G6 wire with a diameter of 2 mm with a current intensity of 350 amps the weight of the fused metal per unit of time by more than 50% exceeds the weight of metal fused during that time by qualitative electrodes with a rod with a diameter of 8 mm of the same steel with current intensity near 500 amps. p40 →

Simultaneously with the development of composition of equipment for welding with magnetic flux has been created.

Experience has shown that ordinary adapters (DSh-5 and similar) of hose semiautomatic machines, intended for welding under a layer of flux are unfit for welding by open arc with a magnetic fluse because of their weight, since during operation the holder must accomplish with the weight the same required manipulations during hand welding.

The first variant of equipment for semiautomatic welding with the application of a magnetic flux consisted of an instrument case which can easily be transfered during a shift of the welder on the article, a special holder with a hose and feed mechanism. Instrument case of this semiautomatic machine has a current relay RT, which is included consecutively in the welding chain. The latter locks directly during contact of an electrode wire with the article. The process of ignition of the arc and support of it is analogous to hand welding. The electrode wire moves the zone of the arc during a short circuit, but this does not hamper excitation of the arc with correctly selected conditions and skillful action of the welder. In electrical system a push button "up" and "down" are provided with the help of which the notor of the feed mechanism is turned on during adjusting movements of the electrode.

Industrial tests showed that with small dimensions and simplicity in handling the equipment has essential deficiencies. Hose adapter DShM-1 of this installation is

facilitated insignificantly as compared to D^{S}h-5. Furthermore the adapter has been designed so that during a small deflection of the bunker from the vertical free access of flux to the welding wire flowing out of the mouthpiece is hampered. Thus welding vertical seams, welding in an angle and so forth becomes impossible. It turns out to be impossible to insulate reliably the mouthpiece of the adapter from external metallic parts.

- Duting interruptions in work it was necessary to turn off the welding generator, since the wire, and sometimes the metallic body of the adapter, being under current, could accidentally short circuit on article.

All these deficiencies were considered during development of the second variant of a semiautomatic machine for welding with a magnetic flux. It was recognized expedient to apply a feed mechanism and instrument case of the PSh-5 semiautomatic machine, not making changes in them, but to design a new adapter, in the design of which deficiencies of the DShM-1 adapter would be eliminated. The DShM-3 adapter, shown in Figure 2, makes it possible to weld both in alow as well as in a vertical position. A special chamber with a flux bunker fixed on it passes flux under action of its gravity from the bunker directly to the section of the wire which emerges from the tip (departure of electrode). This ensures a reliable supply of flux to the arc zone together with the wire during welding in the lower position and in a position near vertical (Fig 4). The DShM-3 adapter weighs almost 500 g, it is very convenient for welding difficult access seams, located in different space positions. The adapter has a facilitated hose, where as the current-carrying part is copper shielding braiding is used, dressed in three layer directly on the spiral, on which the wire passes. Hinged bracing of the flux feeding chamber makes it easy to center the wire in the calibrating hole.

A test of experimental models of the DShM-3 adaptor was conducted in laboratory and industrial conditions at the Kiev "Bol'shevik" Plant and at the Barnaul Boiler Plant.

Tests showed complete industrial fitness and reliability of the adapter.

Figure 2. DShM-3 Hose Adapter for Semiautomatic Welding with Use of a Magnetic Flux.

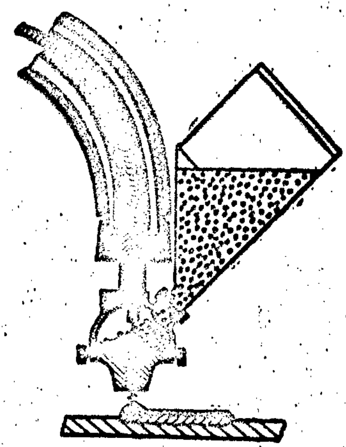

Figure 3. Welding System with a DShM-3 Adapter in Low Position.

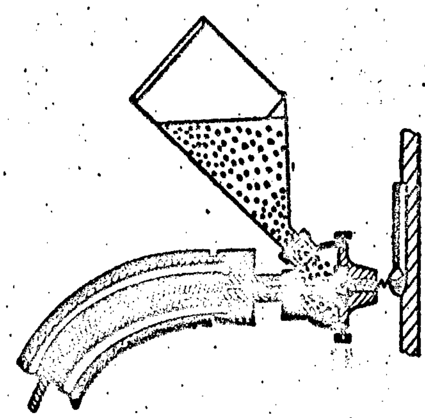

Figure 4. Welding System of with a DShM-3 Adapter in Vertical Position.

A further stage of improvement of technology and equipment for welding with a magnetic flux was the development of equipment for semiautomatic welding in vertical and overhead positions.

Experimentally it was established that the magnitude of welding current does not have to exceed 180 amps for semiautomatic welding in a vertical position and 130 amps in overhead position.

For feeding flux to the wire, flowing from the mouthpiece, it was decided to use carbon dioxide, since from bunker, fastened on the adapter, it is not possible to carry out a reliable supply of flux to the chamber of the adapter.

Therefore flux in the chamber of the adapter moves by hose a stream of carbon dioxide.

On the feeding mechanism of hose semiautomatic machine is fastened a flux apportioning attachment with a bunker. On the exit of the bunker is placed a magnetic cylinder. The flux adhering to the cylinder forms a plug and prevents breaking-out of the remaing flux from the bunker.

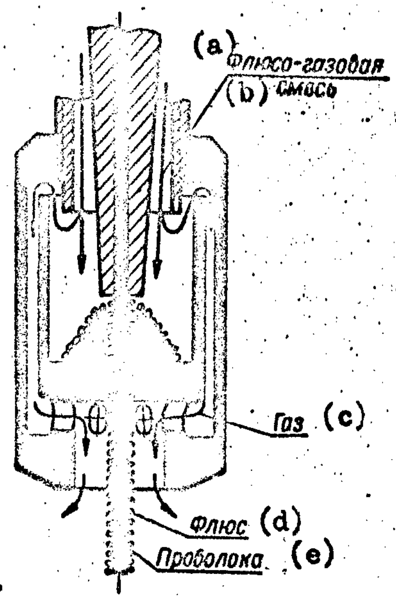

Figure 5. Diagram of the Arrangement of the Flux Chamber of the DShM-4 Hose Adapter

KEY: a) Flux-gas; b) Mixture; c) Gas; d) Flux; e) Wire.

The cylinder is set on a shaft, kinematically connected with the feed roller of the semiautomatic machine. During welding the feed roller, revolving, leads to rotation of the magnetic cylinder. The magnetic flux, adhering to the cylinder, is removed from it with a special scraper and gets in the stream of carbon dioxide, which by the hose transports the flux to the adapter.

In chamber of the adapter the particles of the flux are attracted to the welding wire, and the carbon dioxide, emerging from the chamber, creates an additional protection of the zone of welding.

The first experimental types of adapter for welding

with a thin wire with magnetic flux feed by carbon dioxide had an essential deficiency: during exit of gas from the calibrating hole of the chamber of the adapter the speed of its outflow was increased, grains of flux adhering to the wire were blown off by the gas stream and a bare wire emerged from the adapter.

For removal of this deficiency a design of the chamber of the adapter was created, schematically shown in Figure 5. The chamber has double walls. The flux-gas mixture enters the chamber by a channel, located concentrically relative to the contact mouthpiece. Getting in the chamber, the flux is attracted to the wire, and carbon dioxide by radial clearance between the walls of the chamber emerges outside. Inasmuch as the section of the annular channel between the double walls of the chamber are larger than the section of the outlet of the chamber, a large part of the gas passes through the annular channel. With this the exhaust velocity from the adapter is small and particles of flux are retained on the wire by the magnetic field of the welding current.

The described principle of action was used during development of the DShM-4, adapter which is of simpler design than that preceding it.

The DShM-4 adapter makes it possible to conduct welding in all space positions on currents not exceeding 200 amps.

Bibliography

1. K. K. Khrenov, D.M. Kushnerev, Keramicheskiye Flyusy dlya avtomaticheskoy svarki i naplavki (Ceramic Fluxes for Automatic Welding and Hard-Facing), Gostekhizdat Ukrainian SSR, 1961.

2. N. Davis, R. T. Telford, "Manual magnetic-flux gas-shielded arc welding of mold steel," The welding journal, v. 36, No 5, 1957.

3. D. M. Kushnerev, V. G. Svetsinskiy, "Poluavtomaticheskaya svarka nizkougle rodistoy stali otkrytoy

dugoy s primeneniyem magnitnogo flyusa" (Semiautomatic Welding of Low-Carbon Steels by Open Arc with Use of Magnetic Flux), *Avtomaticheskaya svarka* (Automatic Welding), 1961, No 3 (96).

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RESEARCH ON THE COMPOSITION OF A CERAMIC FLUX FOR AUTOMATIC WELDING OF DOUBLE-LAYERED St. 3 + 1Kh18N9T STEEL

p41 →

/Following is a translation of an article by M. P. Grebel'nik in the Russian-language publication Svarka spetsial'nykh metallov i splavov (Welding Special Metals and Alloys), edited by K. K. Khrenov, Academy of Sciences Ukrainian SSR, Institute of Electric Welding imeni Ye. O. Paton, Kiev, 1963, pp 129-136./

The use of double-layered steels makes it possible to save over 70 percent of expensive high-alloyed steels. However, up to now the problem of automatic arc welding under flux of double-layered steels has not been completely solved for production.

As is known, during welding of low-carbon layer (St. 3) in the case of smelting stainless steel, the fused metal is alloyed by chromium and nickel, as a result of which structures can form which promote the appearance of cracks in the welded seam.

During welding of rust-resistant layers of double-layered steels the smelting of low-carbon St.3 steels is possible. Then the content of carbon in the fused metal will be increased and the quantity of chromium nickel and titanium will decrease, leading to a sharp lowering of its stability against intercrystalline corrosion in an aggressive media.

During welding by split wire the portion of participation of the basic metal in formation of the seam decreases to 35--40 percent [1]. Therefore for decreasing the portion of participation of low-carbon St. 3 steels in formation of the seam during welding of rust-resistant layers, the latter was welded by a split wire.

Furthermore, since double-layered steels have found wide application in construction of pipelines, where strengthening on the part of the rust-resistant layer is not allowed, welding by split wire is used on the section anticipating removal of the rust-resistant layer.

Selection of a ceramic flux for automatic welding by split wire of rust-resistant layers is based on the following.

1. The flux should ensure minimum oxidation of chromium and titanium in metal of the rust-resistant layer and the wire.

2. The flux should ensure good technological properties: separability of the slag, good forming, absence of pores and cracks.

3. The fused metal and zone of action must possess high corrosional stability. p48 →

Welding was conducted on a TS-17M welding tractor with a special attachment for welding by split wire. In order to obtain a sufficient quantity of chromium and nickel in metal of the seam, standard welding wire of brand Sv07Kh25N13 (GOST 2246-60) was used with a diameter of 3 mm (Table 1).

Table 1

Chemical Composition of the Metal in Percent

(a) Объект анализа	C	Mn	Si	Cr	Ni	Ti	P
(b) Сварочная проволока Св07Х25Н13	0,08	1,68	0,44	23,52	13,50	—	0,031
(c) Сталь Ст.3	0,20	0,87	0,27	—	—	—	0,028
(d) Двухслойная сталь: Ст.3	0,15	0,47	0,19	—	—	—	0,029
(e) 1Х18Н9Т	0,07	1,06	0,46	17,40	10,17	0,45	0,028

KEY: a) Object of analysis; b) Sv07Kh25N13 welding wire; c) St. 3 steel; d) Double-layered steel: St. 3; e) 1Kh18N9T

The existing brand K-8 ceramic flux for automatic welding of rust-resistant chrome-nickel acid-resistant 1Kh18N9t steels during welding by split wire does not obtain the required technological properties.

We began the creation of a new flux with the choice of a slag forming base. For investigation of the technological properties of the flux hard-facing with a split wire of the Sv07Kh25N13 brand under the experimental fluxes on St. 3 steel was conducted. As compared to welding a plate layer, the quantity of chromium, nickel and titanium during hard-facing on St. 3 was lower, which was considered during selection of the flux.

Hard-facing was done on DC of reverse polarity. The conditions of hard-facings were: I_W = 480--500 amps, U_a = 32--35 volts, v_W = 4.45 mm/sec. For obtaining minimum and uniform melting by section, the seam distance between wires was taken as 10 mm. Departure was 35 mm.

As known, during welding of stainless steel it is necessary, as far as possible, to use a basic flux, which ensures maximum preservation of chromium and titanium in metal of the seam. Otherwise from the intense oxidation of these elements, metal of the seam becomes sensitive to intercrystalline corrosion.

During selection the flux was tested parallel with three slag bases: CaO--Cr_2O_3; CaO--Al_2O_3; Al_2O_3--MgO.

As can be seen from the diagrams of fusibility (Figure 1), these systems have a minimum temperature of fusing at the following relationships of the oxides:

$$\frac{CaO}{Cr_2O_3} = 0.92; \quad \frac{Ca}{Al_2O_3} = 1.0; \quad \frac{Al_2O_3}{MgO} = 1.13 \; [2].$$

Since calcium oxide was introduced in the flux with marble, then the first and second relationship will have the

form: $\frac{CaCO_3}{Cr_2O_3} = 1.65$; $\frac{CaCO_3}{Al_2O_3} = 1.78$.

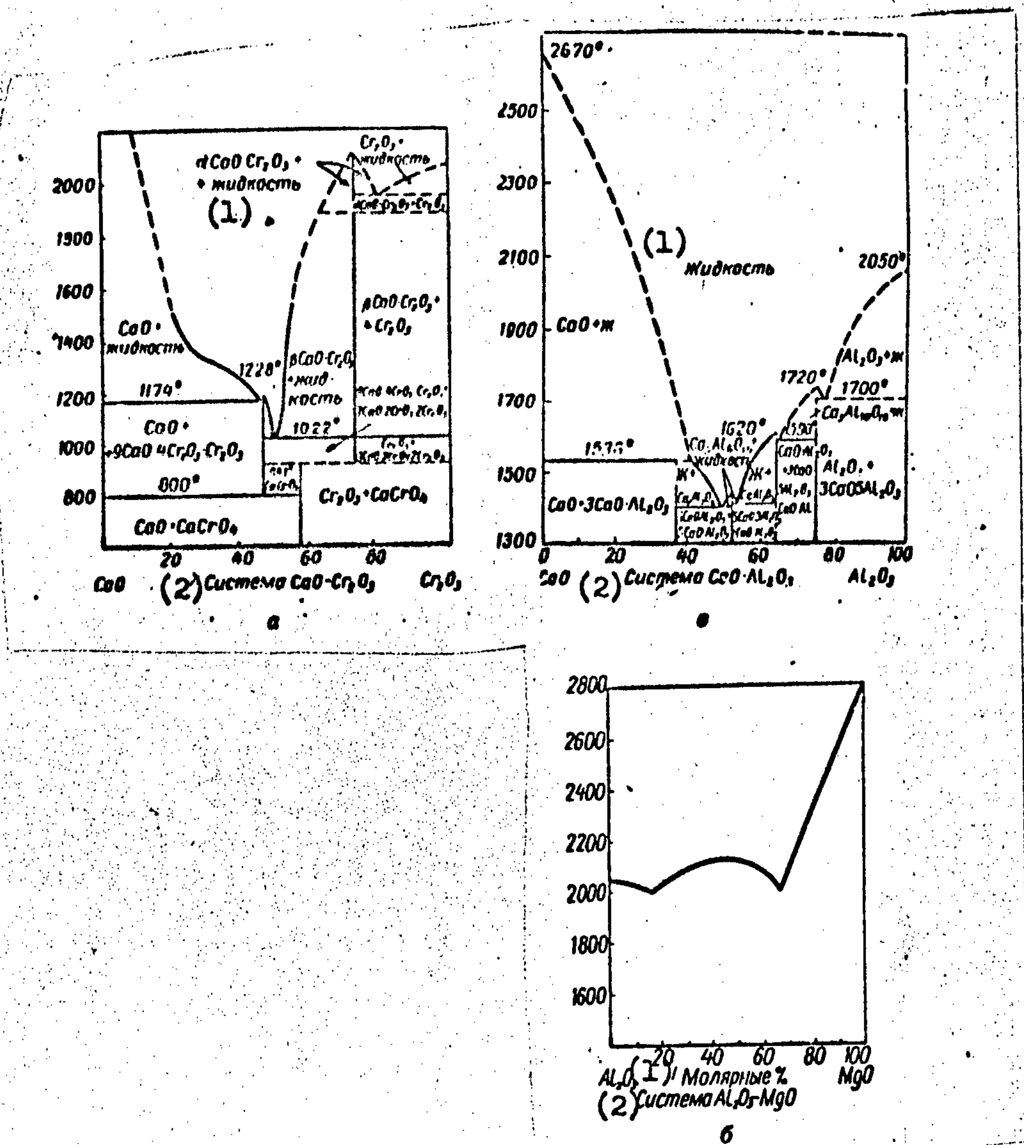

Figure 1. Diagrams of Fusibility of Slag Systems: a) Ca)--Cr_2O_3; b) CaO--Al_2O_3; c) Al_2O_3--MgO

KEY: a: 1) Liquid; 2) Cao--Cr_2O_3 System; b: 1) Liquid; 2) CaO--Al_2O_3 System; c: 1) Molars in percent; 2) Al_2O_3--MgO System.

The chemical composition of the components used in the fluxes is given in Table 2.

In the slag base $CaCO_3$--Cr_2O_3 titanium dioxide was introduced for increasing the transition of titanium. As a result of the experiments, it was determined that these fluxes increase the transition of chromium from the flux, in spite of the presence of marble, capable of oxidizing chromium. In this system the influence of chromium oxide is greater, with an increase of the quantity of which the transition of chromium from the flux is increased. The content of titanium in metal of the seam constitutes a total of 0.03--0.05 percent. With an increase of the quantity of ferrotitanium in the flux above 12 percent a growth of the content of titanium in metal of the seam is not observed (Tables 3, 4). In further investigations it was necessary to eliminate this base due to the poor technological properties of the flux (large fluidity of slag) and low content of titanium in metal of the seam.

Table 2.

Chemical Composition of Components of Fluxes in Percent

(a) Наименование компонентов	CaO	Cr_2O_3	MgO	Al_2O_3	TiO_2	CaF_2	SiO_2	S	P	Si	Ti	Al	Cr
b Мрамор	54,9	—	1,7	—	—	—	6,0	0,03	0,01	—	—	—	—
c Плавиковый шпат	—	—	—	—	—	97,0	3,0	0,05	0,01	—	—	—	—
d Двуокись титана	—	—	—	—	98,0	—	0,03	—	—	—	—	—	—
e Магнезитовый кирпич	2,0	—	96,0	—	—	—	—	—	—	—	—	—	—
f Глинозем	—	—	—	99,0	—	—	0,10	—	—	—	—	—	—
g Окись хрома	—	95,0	—	—	—	—	—	—	—	—	—	—	—
h Ферросилиций, Си75	—	—	—	—	—	—	—	0,02	0,01	76,0	—	—	—
i Ферротитан, Ти1	—	—	—	—	—	—	—	0,03	0,02	—	26,0	—	—
j Ферроалюминий, (50% Al)	—	—	—	—	—	—	—	—	—	—	—	50,0	—
k Хром металлический Х0	—	—	—	—	—	—	—	0,02	0,02	0,4	—	0,4	99,0

KEY: a) Designation of components; b) Marble; c) Fluorspar; d) Titanium dioxide; e) Magnesia brick; f) Alumina; g) Chromium oxide; h) Ferrosilicon, Si75;

i) Ferrotitanium, Til; j) Ferroaluminum, (50% Al);
k) Metallic chromium KhO.

Table 3.

Chemical Composition of Fluxes in Percent

(a) Номер флюса	CaO	Cr_2O_3	CaF_2	TiO_2	SiO_2	MgO	Al_2O_3	FeSi	FeTi	FeAl	(b) Хром металлический
38	18,70	20,03	19,4	11,76	2,64	0,58	--	3,0	6,0	4,0	—
54	15,37	16,70	19,4	11,76	2,28	0,48	—	3,0	12,0	4,0	5,0
55	14,27	15,50	19,4	11,76	2,16	0,44	—	2,0	17,0	2,0	5,0
106	26,8	—	5,82	—	3,12	0,83	26,70	1,0	4,0	1,0	12,0
174	24,2	—	5,82	—	2,84	0,75	23,70	1,0	4,0	1,0	20,0
58	0,49	—	29,10	—	0,93	23,50	27,73	1,5	6,0	—	10,0
59	0,46	—	29,10	—	0,93	22,00	26,23	1,5	9,0	—	10,0
63	0,46	—	29,10	—	0,93	22,00	26,70	1,0	6,0	3,0	10,0

KEY: a) Flux number; b) Metallic chromium.

Table 4.

Characteristic of Fused Metal

(a) Номер флюса	(b) Химический состав, %						(c) Технологические свойства			
	C	Mn	Si	Cr	Ni	Ti	(d) отделимость шлака	(e) формирование валика	(f) растекаемость	(g) чистота поверхности
38	0,13	1,50	0,07	15,7	8,10	0,03	5	5	5	5
54	0,12	0,87	0,73	21,88	8,02	0,05	3	5	5	4
55	0,12	0,83	0,76	19,88	7,28	0,05	2	5	5	3

KEY: a) Flux number; b) Chemical composition in percent;
c) Technological properties; d) Slag separability;
e) Forming of shaft; f) Spread capacity; g) Surface cleanness.

Fluxes on the bases $CaCO_3$--Al_2O_3--CaF_2 ensure easy separability of the slag crust, good forming of the seam, a clean seam surface. During use of them chromium in metal of the seam is lowered as compared to the preceding base, but the transition of titanium is increased and fluxes are short.

During welding of double-layered steels mixing of metal of the rust-resistant layer with the basic metal occurs, not containing neither chromium, nickel nor titanium which are necessary for providing corrosional stability. Therefore besides use of a wire with increased content of chromium and nickel, as compared to the content of it in the plate layer, metal of the seam was alloyed additionally through the flux. As alloying components ferrosilicon, ferrotitanium, ferroaluminum and metallic chromium were introduced in the flux.

Joints of St.3 1Kh18N9T double-layered steel were welded under the experimental fluxes. The thickness of the basic metal was 14mm, the thickness of the plate layer was 3 mm. From the St. 3 a V-form division with 2 mm truncation was produced. Welding was executed by Sv-08 wire under K-11 ceramic flux. Conditions of welding were: I_W = 600--650 amps; U_a = 35--37 volts, v_W = 4.45 mm/sec. After that a division with a width of 16 mm was prepared from the rust-resistant layer with a depth of 3 mm. The rust-resistant layer was welded with a split wire on DC of reverse polarity. Conditions of welding were: I_W = 480--520 amps, U_a = 32--35 volts, v_W = 4.45 mm/sec, distance between wires in light was 10 mm, departure was 35 mm.

Samples for a test on intercrystalline corrosion were prepared from metal of the rust-resistant layer, basic metal of St. 3 was completely removed.

Tests on intercrystalline corrosion were conducted according to the AM method according to GOST 6032-58.

The content of chromium in metal of the seam during welding under fluxes on the base $CaCO_3$--Al_2O_3--CaF_2 is not sufficient for providing necessary corrosional stability. Additional introduction in the flux of 12 percent metallic chromium prevents intercrystalline corrosion in metal of the seam directly after welding. After two-hour tempering at 923 degrees K, the welded seams are struck by intercrystalline

corrosion. During introduction in the flux of an additional 20 percent metallic chromium metal of the welded seam becomes stable against intercrystalline corrosion both directly after welding as well as after two-hour tempering at 923 degrees K, tables 3, 5, fluxes 106, 174.

Fluxes on the base $CaCO_3$--Al_2O_3--CaF_2 ensure excellent technological properties. But in this system the oxidizing properties of marble appear greater which partially oxidizes the metallic chromium introduced in the flux. Therefore, it was necessary to introduce up to 20 percent metallic chromium in the flux.

Fluxes on the Al_2O_3--MgO--CaF_2 base by transition of chromium to metal of the seam occupy an intermediate position between the two preceding slag bases. The transition of titanium is the same as in the flux on the $CaCO_3$--Al_2O_3--CaF_2 base. Aluminum-magnesian fluxes are short, which is bad, since gasses do not always succeed in emerging from the liquid metal through the slag and then on the surface of seams a groove appears in the form of a worm hole.

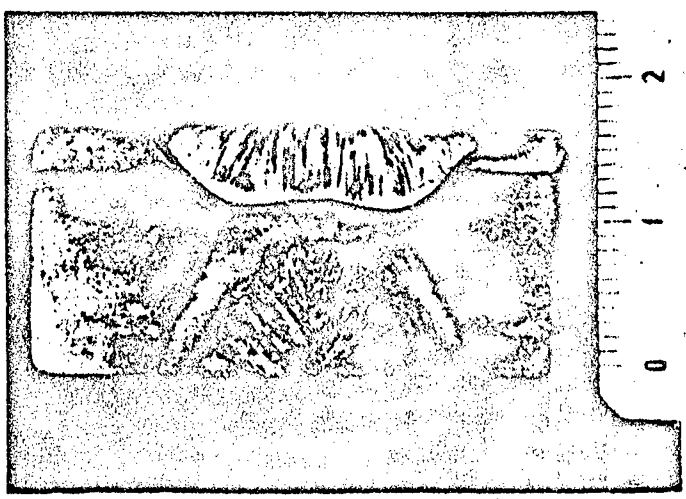

Figure 2. Macrograph of a Welded Joint Carried Out under Flux 58.

From the fluxes tested on this series the best corrosional stability was obtained with fluxes 58, 59, 63.

Samples were tested in a condition after welding and after two-hour tempering at 923 degrees K. After boiling the samples bent outside the rust-resistant layer and the side adjacent to the St. 3. As tests showed, intercrystalline corrosion was not observed in one of the four cases.

Table 5.

Characteristics of the Fused Metal

(a) Номер флюса	(b) Химический состав, %						(c) Наличие межкристаллитной коррозии			
							(d) При изгибе нержавеющим слоем наружу		(e) При изгибе сталью Ст. 3	
	C	Mn	Si	Cr	Ni	Ti	(f) после сварки	(g) 923°K — 2 часа	после сварки	923°K — 2 часа
106	0,12	1,15	0,36	18,00	9,8	0,13	Нет	Есть	—	—
174	0,12	1,10	0,40	21,0	8,73	0,12	Нет	Нет	—	—
58	0,12	1,22	0,98	22,2	9,84	0,17	Нет	Нет	Нет	Нет
59	0,10	1,65	1,70	23,0	8,92	0,30	Нет	Нет	Нет	Нет
63	0,11	1,58	1,68	22,3	9,12	0,24	Нет	Нет	Нет	Нет

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KEY: a) Flux number; b) Chemical composition in percent; c) Presence of intercrystalline corrosion; d) With bend by rust-resistant layer outside; e) With bend by St. 3 steel; f) After welding; g) 923 degrees k -- two hours.

As a result of the investigations conducted it was observed that the best by technological properties is flux 58. A macrograph of a welded joint accomplished under this flux is shown in Figure 2. Furthermore, metal of the seam, welded under this flux, least of all is subject to brittleness.

Metal of a welded seam of the rust-resistant layer has an austenitic-ferrite structure (Figure 3.) In the transition zone from rust-resistant layeer to metal of St. 3 a zone with high brittleness is not observed (Figure 4).

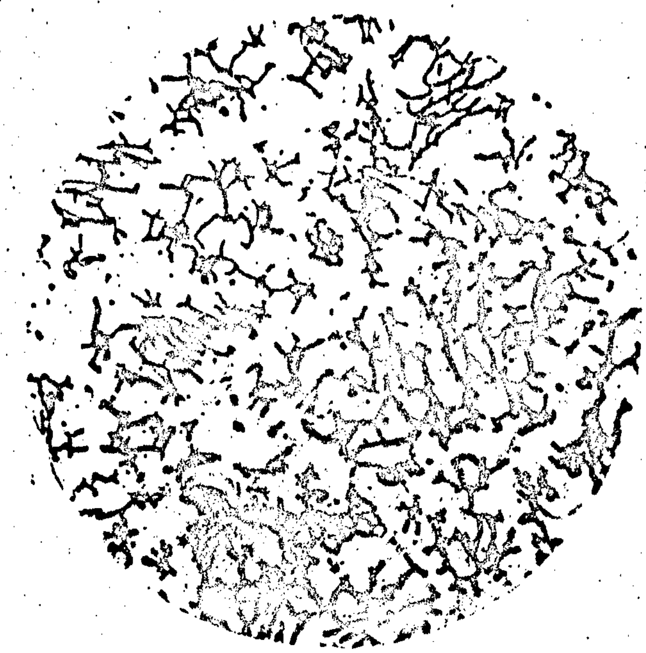

Figure 3. Microstructure of Metal of the Welded Seam of a Rust-Resistant Layer of Double-Layered Steels Carried out Under Flux 58, Magnified 340X.

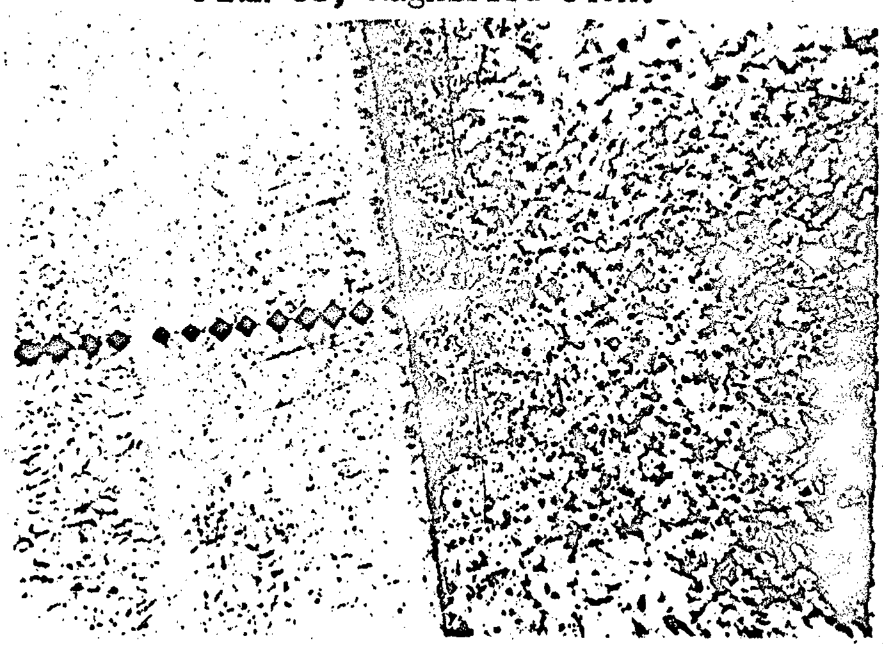

Figure 4. Microstructure of Metal of the Transition Zone, Magnified 340X.

Bibliography

1. B. I. Medovar, A. G. Potap'yevskiy, Ob avtomaticheskoy svarke rasshcheplennym elektrodom (Concerning automatic welding by a split electrode), Avtomaticheskaya svarka (Automatic Welding), No 3, 1955.

2. E. M. Levin, H. F. M. Murdie, F. P. Hall, "Phase Diagrams for Ceramists," The American Ceramic Society, 1956

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CSO: 1879/D-PE

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